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13. ABSTRACT *(Maximum 200 words)*

An infrastructure resource is being created for use by researchers working on computerized image analysis algorithms to aid in mammogram screening. The resource will contain 3,000 cases of data. Each case will consist of 4 images plus associated data. The resource will be available to the research community over the internet and on tapes sent through the mail.

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Enclosure 1

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Kevin W Bamyer 27 July '95
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Contents

1 Introduction

The goal of this project is to establish a database for use by the digital mammographic image analysis research community. The primary purpose of the database is to facilitate sound experimental research in the development of computer algorithms to aid in screening. The database will eventually contain approximately 3,000 cases. Each case will include the standard two images of each breast, meaning a total of 12,000 individual images. Along with the images, each case will contain some associated patient information and specification of parameters of the image acquisition and digitization process.

Previously, most research on computer image analysis for mammogram screening has used a "small" (10s to perhaps 100) number of images. Also, researchers have generally not been able to evaluate their work using the same images used by other researchers. The infrastructure resource created through this project should address both of these problems.

2 Body

This section outlines the conceptual organization of the database in terms relevant to the context of a screening program. Details of the particular file format and storage media will evolve over the course of the project and are not discussed in detail here.

2.1 Database organized as cases

At the highest level, the database is organized as a set of approximately 3,000 individual cases. A "case" is defined as a standard screening exam of two images of each breast, plus selected additional non-image information.

The cases will be divided across five broad categories of result, as defined immediately below. To guard against inadvertent bias in selection of cases, the majority of the cases will be selected "in sequence." See section 2.8 for the definition of "in sequence".

2.2 Distribution of cases across five highest-level categories

The five categories of cases are: (1) *clearly normal*, (2) *normal after recall*, (3) *abnormal – benign*, (4) *abnormal – cancer* and (5) *false negative*. This categorization is chosen to be relevant in the context of a screening program. The planned approximate number of cases in each category is as follows:

clearly normal	800
normal after recall	200
abnormal – benign	1,000
abnormal – cancer	1,000
false negative	≈ 10

2.3 Definition of "clearly normal"

This category is defined as cases presented for screening which:

- were read as normal from the standard screening exam of two views of each breast, **and**
- had a subsequent exam four years later (plus/minus six months) which was also read as normal with no more work-up than additional views, **and**
- for which there is no clinical evidence of malignancy.

Note that the *early* case, not the follow-up case, is the "clearly normal" case that goes into the database. A case which falls into this category has, by this definition, no suspicious region in any of the four images.

2.3.1 Breakdown of "clearly normal" by ACR density rating

The American College of Radiology "BI-RADS" terminology specifies a rating of breast density on a scale of 1 ("almost entirely fat") to 4 ("extremely dense") [1]. Each of the cases in the database will be accompanied by a value for the breast density rating, as assigned by an expert mammographer. The breast density rating is assumed to be the same for all four images in a given study. (**Note** – all of the standard caveats about observer variability apply to the breast density ratings assigned to the cases.)

The four categories of breast density do not occur with equal frequency in the typical screening population – the highest density rating occurs least frequently. Also, It is generally believed that a higher breast density rating presents a greater challenge for correct interpretation. So that there is a sufficient number of the highest-density breasts to allow construction of reliable classifiers, each breast density subcategory will be represented by at least 15% of the total "clearly normal" cases.

2.4 Definition of "normal after recall"

This category is defined as cases presented for screening which:

- were read as normal only after the reading of additional views beyond the standard screening exam, **and**
- had no need of follow-up other than the additional views, **and**
- have had at least four years of subsequent negative screening exams.

A case which falls into this category has, by this definition, at least one suspicious region in at least one image. Each image which contains a suspicious region has an associated "overlay" which records the location and type of the region.

2.5 Definition of "abnormal – benign"

This category is defined as cases presented for screening which contained a suspicious area that was determined to be benign on the basis of (a) biopsy, or (b) the clear demonstration of a cyst by ultrasound or aspiration. A case in this category has at least one suspicious region in at least one image, and each such image has an associated overlay file.

2.6 Definition of "abnormal – cancer"

This category is defined as cases presented for screening which contained a suspicious area that was determined to be cancer on the basis of biopsy. A case in this category has at least one suspicious region in at least one image, and each such image has an associated overlay file.

2.7 Definition of "false negative"

This category is defined as cases presented for screening which were initially read as *clearly normal* or as *normal after recall*, but were later determined to have a cancer present. This category is further sub-divided into cancers which are (a) "clear in retrospect," and (b) "not clear in retrospect." The images for a case in this category may or may not have an associated overlay file.

2.8 Selection of cases "in sequence"

In order to avoid any inadvertent selection bias, and to try to at least partly reflect the natural variability seen in a screening program, the first 80% of the cases in each (sub)category as described above will be taken "in sequence" from the stream of cases at an institution. This means (a) choosing a time period, (b) considering each case in sequence in that time period, and (c) accumulating each case into the appropriate (sub)category until the required number has been met.

As an example, consider the selection of "clearly normal" cases at a given institution. Say that the selection period begins June 1, 1995 and runs until sufficient cases are acquired. Starting with June 1, each case that is read as clearly normal is checked to see if there was a study done in the window of 42 to 54 months previous (4 years +/- 6 months). If such a previous study exists, and it was read as clearly normal, and it is of reasonable technical quality, then that study is accumulated for the database.

Once 80% of the planned number of cases in a (sub)category are accumulated, the characteristics of the cases accumulated to that point will be reviewed. If necessary, the remaining 20% of the cases may be targeted to exhibit characteristics which are thought to be important but which seem under-represented in the first 80%. The sequence/selected status of a given case is part of the associated non-image information for that case.

3 Digitization of films

Cases selected for the database will have the original films digitized according to the following specifications.

3.1 Spatial and intensity resolution

Based on current knowledge, available technology, and budget constraints, the decision was made to begin accumulating studies for the database using a digitizer capable of a spatial resolution of 21 microns, with an intensity resolution of 16 bits.

3.2 Additional non-image information

Each case will contain the following additional non-image information:

- date that the mammography exam was performed.
- age of patient at the time of the exam.
- film manufacturer, film type, and film processing (extended/regular).
- BI-RADS breast density rating (1, 2, 3, or 4).
- date that the films were digitized.
- institution at which the exam was performed (A, B, C, ...).
- file name.
- number of lines per image.
- number of pixels per line.
- number of bytes per pixel.
- information on suspicious regions in each image:
  - location.
  - rating of subtlety on the following scale:
    5 obvious.
    4 detectable by an unsophisticated medical person.
    3 detectable by a competent, ACR-accredited physician.
    2 reasonably likely to be detected by an expert.
    1 reasonably unlikely to be detected by an expert.
    0 completely occult – any expert would miss it.
  - benign / malignant indication, and type of pathology if malignant.
  - screen detected but visible previously / screen detected / visible de nova.

The motivation for the rating of subtlety is that a bar chart of the ratings of the cases, or selected subsets of the cases, can be used as a qualitative indication of the overall difficulty of the cases considered.

4 Radiologist annotation of "ground truth"

Each case falling in any category other than *clearly normal* will have an "overlay" associated with at least one of the images. The overlay will specify "ground truth" information about the locations and types of suspicious regions in the image.

The information in the overlay originates from an expert radiologist marking on the non-emulsifier side of the film with a narrow-tip grease pencil. A film containing a suspicious region is first marked by the radiologist, the digitized, then cleaned and digitized again.

The following procedures are followed for marking the outline of a suspicious region on the film. In all cases, the markings are acknowledged to be approximate, based on best judgment from the information presented in the image.

non-specific suspicious region. The radiologist will mark the outline of the suspicious region as a single closed curve.
circumscribed lesion. The radiologist will mark the outline of the lesion as a single closed curve.
cluster of microcalcifications. The radiologist will mark the outline of the cluster as a whole as a single closed curve. In addition, 3 or more of the calcifications in each cluster will be indicated individually by an arrow pointing to each.
spiculated lesion. The radiologist will use whichever of two approaches they deem most suitable to the particular lesion. (1) The border of the lesion will be marked as a single closed curve intended to capture the rough shape of the lesion; the result will include major spicules, but not necessarily all spicules, and may include some tissue that is not part of the lesion. (2) The central mass of the lesion will be drawn as a single closed curve and major spicules or groups of spicules will be marked as single lines running down the rough center of the spicule.
architectural distortions and asymmetries. The radiologist will draw a closed-curve outline around the border of the suspicious region, intended to capture the dominant shape of the suspicious area but perhaps not its fine detail.
Note – In order to acquire experience with the simpler tasks first, the accumulation of studies is beginning with "clearly normal" cases. The details of the approach outlined in this section may change prior to other categories of cases being accumulated for the database.

4.1 Availability to the research community

The first release of data acquired as part of this project should become generally available to the research community in the near future. We will initially support access to the database via ftp over the internet and via 8 mm "exabyte" tapes sent through the mail. We expect to expand to handle additional tape formats and optical disk as technology progresses. We are continuing to provide ftp access to an existing database of images provided by Nico Karssemeijer and used in his published work on algorithms for the detection of microcalcifications [2,3]. The Appendix provides a log of ftp accesses to this data during the previous year.

5 Conclusions

The use of a large, common database of high quality mammogram images with radiologist-specified ground truth should improve the quality and speed the progress of research in computer image analysis as an aid to screening. We are in the first year of a four-year project to establish such a database. The digitizer has been acquired and installed at Massachusetts General Hospital. Images are being transferred to the University of South Florida. Details of file formats, compression and other considerations are being finalized prior to making initial data from this project available to the community. Even though data acquired under this project is not yet available to the research community, nearly 70 distinct login ids initiated ftp sessions with the USF site in the last year for purposes of transferring (older) mammogram images.

6 References

1. D.B. Kopans, C.J. D'Orsi, D.D. Adler, L.W. Bassett, R.J. Brenner, G.D. Dodd, S.A. Feig, M.A. Lopiano, R.McLelland, M. Moskowitz, E.A. Sickles. Breast Image Reporting and Data System. American College of Radiology. May 1993.

2. N. Karssemeijer. Adaptive Noise Equalization and Image Analysis in Mamography. Proceedings Information Processing In Medical Imaging (IPMI), Flagstaff, June 1993.

3. N. Karssemeijer. Adaptive Noise Equalization and Recognition of Microcalcification Clusters in Mammograms. Special issue of 'Int. Journal of Pattern Recognition and Image Analysis' on digital mammography, Vol. 7, No. 6, 1993.

A Log of Internet FTP Accesses in the Past Year

The following is an abstract from the log of ftp accesses made to the address `figment.csee.usf.edu` for the directory `pub/mammograms` during the period 1 July 1994 through 30 June 1995. All but the first entry for any given login id have been deleted. (In many cases, one login id accounted for many distinct login sessions at different times during the year, and some sessions resulted in as many as 100 transaction entries in the log file.) The internet addresses in the log file reveal a wide breadth of military, commercial, government and university institutions in the United States, as well as many accesses from outside the US.

1. Mon Aug 8 11:30:20 1994 2146 kodaki.kodak.com 3647059
   /pub/mammograms/nijmegen-images/c17c.ima.Z b _ o a _/05Hu@
2. Mon Aug 8 12:25:33 1994 456 kodaki.kodak.com 1522729
   /pub/mammograms/nijmegen-images/c16c.ima.Z b _ o a pawlicki@kodak.com
3. Mon Aug 15 15:02:46 1994 1 fugu.Colorado.EDU 2882
   /pub/mammograms/nijmegen-images/ReadMe.2 a _ o a sharpe@
4. Tue Aug 16 11:37:45 1994 1 picard.coma.sbg.ac.at 2601
   /pub/mammograms/nijmegen-images/ReadMe.1 b _ o a uhl@
5. Tue Aug 16 15:14:51 1994 1 129.92.140.47 2882
   /pub/mammograms/nijmegen-images/ReadMe.2 a _ o a ckocur@afit.af.mil
6. Mon Aug 22 17:36:21 1994 1 pipeline.com 2601
   /pub/mammograms/nijmegen-images/ReadMe.1 a _ o a -gopher@pipe1.pipeline.com
7. Thu Aug 25 11:42:18 1994 17 vision.csee.Lehigh.EDU 307215
   /pub/mammograms/registration/pair1_image2_iw.pgm b _ o a nsv2@vision.csee.lehigy.edu
8. Fri Aug 26 17:36:22 1994 1 atilla.afit.af.mil 2882
   /pub/mammograms/nijmegen-images/ReadMe.2 a _ o a jkelley@afit.af.mil
9. Mon Aug 29 10:32:12 1994 1 maze.ruca.ua.ac.be 2601
   /pub/mammograms/nijmegen-images/ReadMe.1 b _ o a meersman@
10. Mon Aug 29 22:58:43 1994 7 zeus.ee.uwa.edu.au 2882
    /pub/mammograms/nijmegen-images/ReadMe.2 a _ o a chandra@ee.uwa.edu.au
11. Sat Sep 3 12:55:51 1994 12 eustis.cs.ucf.edu 792725
    /pub/mammograms/nijmegen-images/c19c.ima.Z b _ o a calin@cs.ucf.edu
12. Tue Sep 13 08:03:13 1994 1 boifzc.cineca.it 2049
    /pub/mammograms/announce.ascii b _ o a zannoni@boifcc.cineca.it
13. Thu Sep 15 10:55:01 1994 15 crdras.GE.COM 82251
    /pub/mammograms/registration/for_malek/LCC.pgm.Z b _ o a rjmitchell@crd.ge.com
14. Thu Sep 15 22:05:15 1994 1 palomar.ecn.purdue.edu 5248
    /pub/mammograms/nijmegen-images/c17c.lab.Z b _ o a chuang@
15. Tue Sep 20 11:44:12 1994 1 alpha3.rad.med.umich.edu 2049
    /pub/mammograms/announce.ascii a _ o a wei@alpha3.rad.med.umich.edu
16. Thu Sep 22 23:28:39 1994 1 banner.ecn.purdue.edu 2601
    /pub/mammograms/nijmegen-images/ReadMe.1 a _ o a ke@purdue

17. Mon Sep 26 10:30:30 1994 1 kodaki.kodak.com 2049
    /pub/mammograms/announce.ascii b _ o a flure@kodak.com
18. Fri Sep 30 19:48:54 1994 1 grad 2601
    /pub/mammograms/nijmegen-images/ReadMe.1 a _ o a freeman@grad.csee.usf.edu
19. Mon Oct 3 19:23:14 1994 1 garlic.ece.utexas.edu 2601
    /pub/mammograms/nijmegen-images/ReadMe.1 b _ o a chris@
20. Fri Oct 21 06:52:29 1994 1 143.50.41.3 2601
    /pub/mammograms/nijmegen-images/ReadMe.1 a _ o a graif@bkfug.kfunigraz.ac.at
21. Thu Nov 3 14:46:37 1994 1 ultb-gw.isc.rit.edu 2049
    /pub/mammograms/announce.ascii a _ o a joc8048@ultb.isc.rit.edu
22. Thu Nov 3 15:19:24 1994 6 fractal.ee.rochester.edu 2049
    /pub/mammograms/announce.ascii a _ o a cchen@ee.rochester.edu
23. Mon Nov 7 16:56:14 1994 1 freud.ul.rp.CSIRO.AU 2601
    /pub/mammograms/nijmegen-images/ReadMe.1 a _ o a ht@ul.rp.csiro.au
24. Wed Nov 9 05:30:44 1994 1 skopelos.csi.forth.gr 68
    /pub/mammograms/nijmegen-images/c01c.mrk a _ o a chronaki@csi.forth.gr
25. Wed Nov 9 21:56:10 1994 1 bos1f.delphi.com 2049
    /pub/mammograms/announce.ascii a _ o a ALLAN79@DELPHI.COM
26. Thu Nov 17 12:14:31 1994 8333 skopelos.csi.forth.gr 1007616
    /pub/mammograms/nijmegen-images/c01c.ima.Z b _ o a telemed@doris.forth.gr
27. Mon Nov 21 04:51:38 1994 1 jupiter.ceng.cea.fr 2049
    /pub/mammograms/announce.ascii a _ o a dinten@dsys.ceng.cea.fr
28. Wed Nov 23 09:16:50 1994 1 EESUN2.TAMU.EDU 2601
    /pub/mammograms/nijmegen-images/ReadMe.1 a _ o a shayne@tamu.edu
29. Fri Nov 25 14:24:50 1994 1 xor.ece.iit.edu 2882
    /pub/mammograms/nijmegen-images/ReadMe.2 b _ o a gwang@ece.iit.edu
30. Sat Nov 26 11:32:03 1994 1 cortex.ama.ttuhsc.edu 68
    /pub/mammograms/nijmegen-images/c01o.mrk b _ o a roberto@cortex
31. Mon Nov 28 11:15:54 1994 158 EESUN2.TAMU.EDU 1823797
    /pub/mammograms/nijmegen-images/c02o.ima.Z b _ o a lee@tmu
32. Tue Nov 29 09:59:47 1994 341 mira.cc.umanitoba.ca 1935653
    /pub/mammograms/nijmegen-images/c06o.ima.Z b _ o a luchka@ccu.umanitoba.ca
33. Wed Nov 30 10:44:10 1994 1 philabs.philips.com 2601
    /pub/mammograms/nijmegen-images/ReadMe.1 b _ o a msa@philabs.philips.com
34. Tue Dec 6 19:04:37 1994 1 zark.maths.uts.edu.au 2601
    /pub/mammograms/nijmegen-images/ReadMe.1 a _ o a hung@zark.maths.uts.edu.au
35. Mon Dec 12 15:10:37 1994 1 TVAX2.CDRH.FDA.GOV 2601
    /pub/mammograms/nijmegen-images/ReadMe.1 a _ o a jsb@tvax2.cdrh.fda.gov
36. Fri Dec 30 04:07:09 1994 1 cps223.cps.cmich.edu 68
    /pub/mammograms/nijmegen-images/c01c.mrk a _ o a wiley@
37. Tue Jan 10 03:09:37 1995 1 bern.student.uni-tuebingen.de 2049
    /pub/mammograms/announce.ascii a _ o a bernhard.karten@student.uni-tuebingen.de

38. Mon Jan 16 00:00:32 1995 1695 matisse.phys.uts.EDU.AU 1522729
/pub/mammograms/nijmegen-images/c16c.ima.Z b _ o a zen@maths.uts.edu.au

39. Thu Jan 19 03:43:29 1995 1 caretta.engr.umbc.edu 2049
/pub/mammograms/announce.ascii b _ o a xuanj@engr.umbc.edu

40. Thu Jan 19 04:06:58 1995 1 caretta.engr.umbc.edu 2049
/pub/mammograms/announce.ascii b _ o a itl@engr.umbc.edu

41. Sun Jan 22 22:21:19 1995 1 dc4_p22.sprint.dialup.net 2049
/pub/mammograms/announce.ascii b _ o a achristo@inteachristo@interserv.com

42. Fri Jan 27 20:28:31 1995 1 150.148.36.171 2601
/pub/mammograms/nijmegen-images/ReadMe.1 b _ o a jonathan@tvax2.cdrh.fda.gov

43. Tue Jan 31 11:37:15 1995 1 garbi.upc.es 2601
/pub/mammograms/nijmegen-images/ReadMe.1 a _ o a calderon@lsi.upc.es

44. Wed Feb 8 18:11:03 1995 1 gandalf.cs.andrews.edu 2049
/pub/mammograms/announce.ascii b _ o a wolfer@anerew.edu

45. Tue Feb 21 21:03:26 1995 25 grad 2511773
/pub/mammograms/nijmegen-images/c05o.ima.Z a _ o a namuduri@

46. Tue Feb 28 14:25:38 1995 340 selma.trg.SAIC.COM 1233505
/pub/mammograms/nijmegen-images/c06c.ima.Z b _ o a edb@selma.trg.saic.com

47. Mon Mar 6 20:27:56 1995 1 van-gogh.ee.ubc.ca 2601
/pub/mammograms/nijmegen-images/ReadMe.1 a _ o a sameti@ee.ubc.ca

48. Thu Mar 16 17:37:52 1995 1 dsp6.eng.umd.edu 2049
/pub/mammograms/announce.ascii a _ o a farrokhi@eng.umd.edu

49. Mon Mar 27 16:07:12 1995 1 calypso.NMSU.Edu 24
/pub/mammograms/nijmegen-images/c03o.mrk b _ o a sanaya@vrl.com

50. Sun Apr 2 14:38:00 1995 1 avmac.biophysics.mcw.edu 2120
/pub/mammograms/announce.ascii b _ o a rwcox@mcw.edu

51. Tue Apr 4 04:47:55 1995 1 bimigw.kfunigraz.ac.at 2601
/pub/mammograms/nijmegen-images/ReadMe.1 a _ o a gabler@balu.kfun

52. Thu Apr 6 12:59:48 1995 2 freewill.tu-graz.ac.at 4234
/pub/mammograms/nijmegen-images/c19c.lab.Z b _ o a mforst@sbox.tu-graz.ac.at

53. Tue Apr 11 15:06:48 1995 67 waterfall 1799397
/pub/mammograms/nijmegen-images/c01c.ima.Z b _ o a hall@

54. Thu Apr 13 20:35:56 1995 140 kirchoff.ee.rochester.edu 1799397
/pub/mammograms/nijmegen-images/c01c.ima.Z b _ o a nasan@

55. Fri Apr 14 01:33:53 1995 29 scheifler 1110367
/pub/mammograms/nijmegen-images/c02c.ima.Z b _ o a rashedi@

56. Tue Apr 18 11:47:50 1995 1 MAMMO.PNDR.UPENN.EDU 2601
/pub/mammograms/nijmegen-images/ReadMe.1 a _ o a toto@mammo.pndr.upenn.edu

57. Tue Apr 18 14:56:16 1995 1 tilki4.nswc.navy.mil 2120
/pub/mammograms/announce.ascii b _ o a dmarche@tilki4.nswc.navy.mil

58. Thu Apr 20 21:11:56 1995 270 kurtz.eee.utas.edu.au 1153589
/pub/mammograms/nijmegen-images/c19o.ima.Z b _ o a H.Talhami@eee.utas.edu.au

59. Tue Apr 25 10:50:14 1995 1 131.174.82.77 4171
    /pub/mammograms/nijmegen-images/c01c.lab.Z b _ o a nico@mbfys.kun.nl

60. Wed May 17 15:42:35 1995 1 zztop.eng.usf.edu 3472
    /pub/mammograms/nijmegen-images/c01c.lut.Z b _ o a naiyer@

61. Thu May 18 00:20:06 1995 1 dixie.cs.ubc.ca 4171
    /pub/mammograms/nijmegen-images/c01c.lab.Z b _ o a bandari@

62. Tue May 30 10:09:52 1995 1 cnea.edu.ar 2717
    /pub/mammograms/nijmegen-images/ReadMe.1 a _ o a gameor@cmea.edu.ar

63. Wed Jun 7 10:28:04 1995 1 tk13.oulu.fi 2717
    /pub/mammograms/nijmegen-images/ReadMe.1 b _ o a hannu@ee.oulu.fi

64. Sat Jun 17 23:53:39 1995 1 grad 3472
    /pub/mammograms/nijmegen-images/c01c.lut.Z b _ o a henrique@

65. Sun Jun 18 11:40:14 1995 24 paris.eng.utsa.edu 194077
    /pub/mammography_papers/mic92.ps.Z b _ o a yzhou@

66. Tue Jun 27 15:43:28 1995 1 iris.stsci.edu 2120
    /pub/mammograms/announce.ascii a _ o a hanisch@stsci.edu

67. Thu Jun 29 14:08:22 1995 1 lab-pc-61.bus.umich.edu 4213
    /pub/mammograms/nijmegen-images/c01o.lab.Z b _ o a Netscape@lab-pc-61.bus.umich.edu

68. Fri Jun 30 17:44:07 1995 1 sunflash 4171
    /pub/mammograms/nijmegen-images/c01c.lab.Z b _ o a weyron@